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(54) Message-based debugger.

(57) Method for programs debugging and testing of their correctness consisting in the loading in a data processing system, of a monitoring program, of at least a source program to be tested and of at least an object program obtained by the source program through a preprocessing which includes, at each executable program row, a call to a control routine, in the independent activation of a monitoring process based on the monitoring program and of a process to be tested, based on the object program, the two processes interacting by means of message queues.

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The present invention relates to a method for program debugging and testing of their correctness.

It is know that testing of the correctness of programs for data processing systems is a basic problem in the EDP field.

This problem has not been entirely solved, in spite of the several analysis and test tools which have been adopted.

A basic reason for the difficulty in testing the correctness of a program is that the program behaviour largely depends on the data on which the program operates and, in case of interactive programs, on the information (data and commands) received from a user.

Therefore even if an exaustive testing is often impossible program testing and verification is preferably conducted by causing the program to operate with some data.

In other words, what is defined as "process" by software designers is created and performed.

A "process" is commonly defined as an address space, a control thread operating within the address space and the set of system resources needed for operating with such thread.

Process is therefore a logic entity consisting of the program itself, of the data on which it must operate and of the memory resources and input output resources required for running the process.

Therefore the program verification and the detection of errors (bugs) is reconducted to the execution of the program as a process thread, to test if the process develops in correct way or if undesired or unexpected events occur.

To test a process in the course of its running, the prior art offers two basic tools:

tracing functions or TRACERS

symbolic analysis functions or SYMBOLIC DEBUGGERS.

The tracing functions modify a program to be tested so that each program instruction is preceded and followed by instructions which control the printing of the instructions and possible variables used by the instruction before and after the instruction execution.

The symbolic analysis functions are basically interactive programs which starting from a source program to be tested (in a high level language such as the C language), treated as a data file, generate a compiled program as an executable copy of the source and modify it so that for each source code instruction it performs a routine which, by means of conditional branches to other routines, allows the user to see on a screen the several instruction sequences and to selectively set break points after each instruction of the object program, using the source displaying as a reference.

The symbolic debuggers further enable the insertion, in the object program, of routines for recording the variables used in the instruction execution and, on user request, they provide break point lists and used variables, displaying them on a screen and enabling the user to add, remove break points, to modify variables, to test the program functions in differing environments.

These tools are particularly effective, in that they permit to control the execution of a program, that is the evolution of the related process by halting and restarting it at will, by changing parameters in the process course, the whole by means of displaying windows which allow for the monitoring of the process status and for its control through intellegible indications.

However effective, such tools suffer of severe limitations.

First of all they can test and operate on a single process at a time. The monitored process is treated as a "child" process of the symbolic analysis function or process.

That means that in case of more interactive processes the monitoring can be performed on single non interactive process phases, which have to be obtained by severing the program in segments.

Otherwise it would be required to link the several programs so as to generate a single process whose evolution is extremely difficult to be followed, even at symbolic level.

Further the process to be tested must be activated by the father process (the symbolic analysis process) and cannot be activated earlier.

Therefore the debugging of programs which are activated at system start up (monitor, daemon etc.) is impossible.

Eventually, since the process to be tested is generated as a child of the symbolic analysis process and in a certain sense is the result of a combination of the symbolic analysis function/program with the program to be tested, the two processes mus have the same resources. As a consequence interactive programs which make use of masks and windows and therefore need a terminal, cannot be tested because they interfere with the symbolic analyser in the access to the displaying and control terminal.

These limitations are overcome by the method for program debugging and testing of their correctness which is the object of the present invention.

The method makes use of the following concepts.

The process or the processes to be tested, in the following identified shortly ~~h~~as PUT are created as

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processes distinct from the monitoring process or processes.

- The monitoring processes communicate with the PUTs by means of messages which are stored in a queue of messages addressed to the PUTs.
- The several PUTs communicate with the monitoring process or processes by means of messages which are stored in message queues, one for each monitoring process, the messages addressing one of the monitoring processes.
- since the several PUTs have to interact with the monitoring processes by means of queues, the several PUTs ae performed based on archives or executable files in object language, the files being obtained by preprocessing of the source program to be tested. Preprocessing, in addition of performing the obvious compilation from source to object, provides for the insertion at each instruction or instruction row of the source program, of an instruction (xx) calling a function or routine (X-F) which has the task to read the queue of messages sent to the PUTs and to operate accordingly.

It further has the task of writing, on the occurrence of certain conditions, suitable messages in the message queue of the monitoring processes.

- one of the conditions which the function X-F has to monitor is the presence of a BREAK POINT (BP) before the instruction to be executed.
- Such break points are set by operator by means of the monitoring processes. Information related to such break points is stored in break point tables BPTABLE, to which both the monitoring programs and the programs to be tested must have access.
  Therefore such tables must be shared resources.
- Since a debugging or test operation implies the generation and running of distinct and intercommunicating processes, to make possible simultaneous debugging operations in a multiuser environment it is required to provide means for avoiding interference and confusion among user, by identification of differing debugging sessions.
- In order to avoid interference in the user-process interaction, the set of monitoring processes and the set of PUTs each preferably comprise distinct I/O resources (terminals).
- In order to have a more effective debugging in case of interaction among several processes, hence the need to test several processes, a "background" monitoring function is provided so as to test several processes in parallel, by prearranging suitable test operations and test conditions.

The features and the advantages of the invention will appear more clearly from the following description of a preferred form of implementation and from the enclosed drawings where:

- Figure 1 shows the hardware resources essential to the performance of the method of the invention.
- Figure 2 shows the programs or executable files essential to the performance of the method of the invention.
- Figure 3 shows in flow diagram the operations to be performed to start a monitoring process
- Figure 4 shows in flow diagram the operations to be performed to start a process to be tested (PUT).
- Figure 5 shows in block diagram the structure of the system for implementing the method of the invention.
- Figure 6 shows in block diagram the logical and hardware resources used in performing the method of the invention.
- Figure 7 shows in flow diagram the essential operations performed by a control function x-F used in the method of the invention.
- Figure 8 shows in flow diagram the main functions performed by a control process (main monitor) in the method of the invention.
- Figure 9 shows in flow diagram the main functions performed by another control process (background monitor) in the method of the invention.

Fig. 1 shows the hardware resources needed for performing the method of the present invention.

They comprise a display with keyboard 1, a second display with keyboard 2, a central processing unit or CPU3, with related working memory, and a mass storage 4.

For the performance of the system it is required that the files needed for the generation of the several processes be stored in storage 4.

The files are shown in fig. 2 and are:

- a file VDB MONITOR in object format
- a file XTRACE in object format, the file performing the function of modifying a source file to be tested, by incorporating in each row of the source file a call to a function x-F.
- an x-F function file (which may be a VDB MONITOR file).
- a COMPILER file for compiling in object format from a source language, for instance the C language.
- the generical source files a,b forming a first program to be tested.

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- test routine (TEST SCRIPT) files which will be considered in the following.

In order that CPU3 and the debugging system may operate on programs a,b and d,e these files must be preprocessed, giving origin to new source files where each instruction (or instruction line) is preceded by a call to the function x-F.

By means of any of the terminals 1,2 the operator must control the generation of these files by the commands (in C language).

```
x trace a.c     VDB/a.c
x trace b.c.    VDB/b.c

x trace d.c.    VDB/d.c
x trace e.c.    VDB/e.c
```

These commands insert the function x-F and the related calling instruction, in the several sources a,b,d,e (in C language) and generate new C language files having name VDB/a.c; VDB/b.c; VDB/d.c; VDB/e.c.

In order that CPU3 may operate according to the thread defined by these source files, they must be compiled, that is translated in machine language, by means of the following operator commands:

```
cc-g VDB/a.c  VDB/b/c   -lVBD -oprg1
cc-g VDB/d.c  VDB/e.c.  -lVBD -oprg2
```

By these commands two executable files having name prg1 and prg2 in machine language are created. They are linked to the library of functions of the VDB monitor.

The compilation option -g indicates that the relation symbolic name/address of the program variables must be saved to allow for the retrieval of the variables by means of their symbolic name.

All these operation are well known in the art and do not need any additional explanation: it is the contents of the VDB functions which is different.

Once performed these preliminary operations several file types exist in the storage of the Fig.1 system: source files and object files. Once the resources required for operation are prearranged it is required to start the several programs.

According to one aspect of the invention this is made, in case of interactive programs, by using two distinct terminals.

In addition, to enable more users to perform the testing of differing programs at the same time and in the same system, which generally may allow for multiuser operation and may have a number of terminals greater than two, it is provided that each user identify its own testing session so s to avoid conflicts and interference with other users. These two aspects are shown by the flow diagrams of figure 3 and figure 4.

In Fig. 3 the user who wants to open a testing session, defines a testing environment VDBID by identifying with a name "dbg1" its own environment.

This is done by the command setenv VDBID dbg1 (block 6).

Then the user activates the analysis function (block 7) referenced by its own name followed by one among some possible options which establish differing operative modes:

```
-VDB        or
-VDB -s     or
- VDB -pid
```

The commands shown in the flow diagram of Fig.3 and related to the monitoring function VDB must be given through terminal 1, which becomes the terminal through which the monitoring function communicates the status of the process under test to the user.

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In Fig.4 the user who intends to test a program defines the analysis environment VDBID in which the program has to be monitored by means of the command setenv VDBID dbg1 (block 8).

The user must further provide the information needed to retrieve the object files to be executed and monitored and the related source files by means of the commands:

```
setenv VDBSPH "source-file-path-name" (block 9)
setenv VDBOPH "path-name-object-file" (block 10)
```

Then the user may start the execution of the object file with the commands -pid1; -pid2 (block 110)

The commands shown in the flow diagram of Fig.4 and related to the activation of the processes to be tested, are preferably given through terminal 2, which becomes the terminal through which the programs described by files pid1, pid2 may interact with the user.

The activation of the monitoring function is independent of the activation of the programs/processes to be tested and may preceed or follow the second, at will.

This is possible because the monitoring function VDB is a process distinct from those which are generated by the execution of the programs to be tested and because the monitoring VDB and the function x-F included in or called at by the executable files, provide the required synchronization between the two kind of processes.

Figure 5 shows in block diagram the structure of the system for perfoming the method in accordance with the invention.

The showing is in terms of generated processes.

The monitoring program VDB comprises three distinct modules; a keyboard monitor, a main monitor, a background monitor.

When the VDB program is activated, three distinct processes 11,12,13 are created, respectively for controlling the keyboard, for a main monitoring of the process, for a background monitoring.

Even if the three processes may constitute a single process, the severing in a main monitoring process and background process is of advantage because it enables to simultaneously operate with differing modalities on a plurality of processes to be tested.

The severing of the keyboard controlling process from the others is of advantage because in this way the communication mechanism among differing tasks is made homogeneous and the need of branches from message queue monitoring to the monitoring of other conditions is avoided.

It further provides in systematic way compliance with the first in/first serviced criterion in treating the several messages.

Likewise, when the programs referenced by pid1, pid2 are started, two distinct processes 14,15 referenced as PUT1,PUT2 are created, each comprising the function x-F.

The generation of the monitoring processes is completely useless if they cannot interact with the processes to be monitored. This interaction is possible and is made through the exchange of messages among processes. The exchange is performed with the use of a predetermined memory space where to store an ordered sequence of messages.

Thus three memory spaces 16,17,18 respectively named queue Q1, queue Q2, queue 3, are respectively associated to the main monitor 12, to the background monitor 13 and to the set of processes to be tested 14,15.

Other processes may store messages to process 12 in queue Q1, messages to process 13 in queue Q2 and messages to one of the processes 14,15 in queue Q3.

The memory regions 16,17,18 form a shared memory segment which is created and allocated with the activation of any one of the several processes.

It must be noted that the several processes to be tested, even if completely independent of the monitoring processes are logically related to them because they use a common memory space which must be addressed in a consistent way.

The definition of a single queue 18 for messages intended for several processes to be tested 14,15 requires that the messages stored in queue 18 contain a destination process identifier and conversely that the messages stored in queues 16 and 17 by one of the processes to be tested contain a sending process identifier.

Keyboard monitor 11 does not need any message queue because it has the only function of sending messages (commands) to the main monitor 12. The memory regions 16,17,18 are not the only shared

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memory space which is used by the several processes.

A basic function of process 12 (main monitor) is the one to manage (insert, remove) break points which stop the execution of a process to be tested at predetermined points that is at predetermined instruction lines of the program executed by the process.

On the other hand the function x-F in the process to be tested has the task to detect the presence of absence of break points.

It is therefore required to allocate in the shared memory space some regions where to store tables, one for each process to be tested, where to describe the situation of the break points for each process. These tables are basically lists of absolute addresses of instructions in the source files, progressively numbered and in correspondence of which a break point has been set.

In addition to these tables a buffer is provided (25 fig. 6) in the shared memory space, where to store certain information, such as the active inactive state of the monitoring process, the activation options -s, -pid, other commands, dynamically generated at run time, such as for instance a command A (general stop of all processes to be tested) and lists of processes under test.

Figure 6 shown in block diagram the structure of the monitoring system in terms of resources.

Terminal 1 receives, from VDB monitor 27, stored in the working memory of CPU3, information on the status of the PUTs and based on several inputs, such as information contained in status buffer 25, messages stored in the set of queues 19, break point lists stored in tables BPTABLE 20,21, source files 22 and object files 24 (stored in mass memory 4 and moved into the working memory by pages at the extent they are needed) COFF tables 23 (for Common Object File Format), say tables which describe the format of the several files, hence the features of the used variables and the relation symbolic name-address.

The COFF tables too are stored in the mass memory 4 and moved to the working memory when and at the extent they are needed.

The processes to be tested PUT1,PUT2, in turn, operate on the basis of the object files 24, moved from mass storage to working memory, and of information read out from queues 19 and from break point tables 20,21, and further, in case of user interactive processes, on the basis of signals sent to and received from terminal 2.

Test routines or TEST SCRIPT 26 to be performed on a process under test must be provided, compiled, loaded in the mass storage and moved in working memory when required, to perform a background monitoring of processes under test.

Before discussing in more detail which operations are performed by the monitoring processes and by the function X-F in the processes under test PUT, it is advisable to briefly consider what the user needs from the monitoring system and what the system provides, in a context where more processes to be tested are active.

Basically the user needs some means to visualize in a clearly interpretable form, at which point of a program the processes to be tested are.

The user also needs some means to stop the processes under test once each instruction line has been executed or after predetermined instructions.

He further needs to know the value of variables used in the processes and in case to modify them.

Eventually he needs to know the status of the several processes under test.

All these items of information are requested by the user through the keyboard and displayed at the terminal screen by the main monitor, through a plurality of "windows" which the user calls with suitable commands.

When the monitoring process is started, the user receives a first confirmation message on the terminal display:

```
"The VDB monitor is active"
no processes under test are active
```

As soon as a process under test is started the user receives the following message on the terminal screen:

```
"A process having identifier pid has been started"
```

The terminal screen further displays the list of the first lines of the source file corresponding to the process in execution.

Then the user may begin to navigate in the plurality of the available information items, selecting source

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lines, setting and removing break points, reading or writing variables and so on, controlling step by step execution of the process and so on.

As well as other processes to be tested are started (or, if prevously started, as soon as they notify their presence to the main monitor) their starting is signalled on the screen with a message in a predetermined line of the screen.

The remaining portion of the screen continues to display the previous image unchanged and providing information on the first PUT which has been started.

It is the user who decides what he wants to see and may control the change from the visualization of information related to a given process, which is defined as the current process, to the visualization of information related to another process, which becomes the current process, or to the visualization of tables which list the several started processes and their status, so as to select, among them, the process to be visualized, which becomes the current one.

All these details are provided to advance which are the messages and the operations which the monitoring processes have to generate and to manage.

Basically, the keyboard is the instrument by which the user sends commands which are converted, by a keyboard monitoring process, in messages sent to queue Q1 of the main monitoring process.

Figure 7 shows, in flow diagram, the operations performed by the function x-F in the process under test PUT.

Function x-F is triggered before executing each instruction line of each PUT by the first instruction xx found in each line.

A generic process PUT identified by an identifier "pid" may be generated and activated in several ways:

a) with an explicit command -pid

b) with the execution of the primitive FORK by a "father" process for generating a "child" process having the same identifier.

c) with the execution of the primitive EXEC by which the process switches from the execution of one file to the execution of another file, without changing its process identity.

All these events address an instruction line for its execution and therefore they first call for the function x-F.

Function x-F has, among other tasks, the one of detecting and signalling these events to the main monitoring process or main monitor.

Function x-F detects one of these events by testing (block 30) the value of a static variable FIRST which is set to zero by the operating system when the process is created and subsequently set to a value equal to the process identifier pid.

If FIRST is 0 the event which has started the function is a process activation or an EXEC primitive.

Therefore a message is sent (block 31) to the main monitor M.MT indicating that a process identified by a pid, and whose files are retrievable in a directory "DIR" through a "path" has been started (START).

Based on this information the main monitor may detect if the started process is a new one (new pid) or is a process already under test. Function x-F then wait for a reply message from the main monitor.

The message is read in the message queue (block 32).

If FIRST is other than 0, the function x-F checks (block 33) if the new process results from a FORK primitive.

If the check is negative, the function x-F has been called by the instruction xx heading a new instruction line of an already running process and function x-F steps from block 33 to a block 43 which will be considered in the following.

If the event which has started the x-F function is a FORK primitive the function forwards a message to the main monitor (block 34) indicating that the FORK is related to a process defined by a pid having files retrievable in a directory "DIR" through a "path".

Even in this case the function x-F, once sent the message, waits for a reply message and steps to block 32.

On receipt of these messages, the main monitor defines the allocation of break point tables BPTABLE for the processes which have signalled their presence, updates a list of processes under test, display the event on the terminal screen and forwards to the activated process a reply message ACKN, indicating the location of the BPTABLE where to check the presence of break points, and the location of a buffer 25 where to check the status of certain commands such as -s, -pid, A. The option -s (in the command which has started the monitoring process) indicates that all processes under test which signal their presence to the main monitor have to wait for an explicit command in order to proceed.

The option -pid (in the command activating the monitoring process) indicates that the processes which

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have signal led their presence may proceed, except the process which is identified by pid. This process must wait for an explicit consent and becomes the current process under test.

Command A is a STOP command which may be set and reset at "run time" and requests the halting of all processes under test. When the reply message is received from the main monitor, the function x-F restarts.

It sets the FIRST variable equal to its own pid (block 35) and checks if stop commands (-s,A) are present (block 36).

If present, the function x-F waits for an explicit GO message (block 37) on receipt of which the function x-F ends and the process under test proceeds with the execution of the subsequent instruction (or instructions) of the same row (block 38) and the referencing of a new instruction row, with the consequent reactivation of the x-F function. If no STOP command is present but the process under test has the same pid of the activation option (block 39), the function x-F sends a message to the main monitor specifying its own pid and the line number LINE# where the process under test is halted (block 40).

Then it steps to block 37.

It is a task of the main monitor to display the status of the process under test, which becomes the current one.

If the pid identifier is different, the function x-F checks in the buffer if a condition VISUAL is set (block 41).

If this condition is asserted, it sends a message to the main monitor, specifying the line number LINE# of the process under test (block 42) and terminates, allowing the process to proceed with the execution of the further instructions of the same row (block 38).

If the VISUAL condition is deasserted the function x-F ends and the process steps from block 41 to block 38.

If the function x-F is started in the course of an already active process (block 33, FORK condition false) the function steps from block 33 to block 43 and checks, by reading the break point table B.P.TABLE related to the process if a break point has been set for the current instruction row (B.P. SET?).

In the negative case, the x-F function steps from block 43 to block 36 already considered and it is further checked (STOP?) if the test conditions anyhow require a stop or a step by step running.

In the affirmative case (B.P. SET) the function x-F checks (block 44) if the break point is of background type.

If it is of background type a message is sent to the background monitor (msg B.MT) and the line number and file number where the process has been stopped is sent (block 45).

The function x-F then waits for a reply message stepping to block 37 already considered.

If the break point is not of background type, a message is sent to the main monitor (msg.M.MT) specifying the line number and file where the process is stopped (block 46) and the function x-F steps to block 37 waiting for a reply message in order to proceed.

Figure 8 shows in flow diagram the basic operations performed by the main monitor M.MT.

Basically the main monitor has to manage the interaction of the x-F function of all processes under test and the user interactions through terminal screen and keyboard monitor.

The typical activity of the main monitor is therefore to check for the presence of a message addressed to it, to recognize the contents of the message and provide accordingly with a continuous recycling. Once the main monitoring process is started (-VDB command) the main monitor checks the presence of messages in the queue Q1 (block 50). When a message is received, the main monitor tests if the message has been sent by a process under test PUT, by keyboard, or by the background monitor (block 51).

If the message is originated by a PUT it is first checked (block 52) if it is a START or a FORK message (blocks 31,34 of fig. 7).

In the affirmative case, the list of processes under test is updated (UPD P.TAB) by adding the new process to the list, if not already present, by allocating a break point table (ALLOC BPT) for the new process and building, loading or copying in working memory the required COFF tables (block 53).

Once these operations are performed the main monitor tests if the message has been originated by a process identified as the current one (block 54) and in the affirmative the related source file is loaded in working memory (LOAD S. FILE), if not already present and suitable commands (SCR.MG) are sent to the screen to display the event (block 55).

Then a confirmation message ACKN is sent to the message queue Q3 of the processes under test (block 56) and the main monitor returns to block 50.

In the negative case the main monitor steps from block 54 to block 56.

If the received message is not a START or a FORK message it is tested if the message has been originated by a break point, or stop, or a VISUAL condition (block 57).

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In case of break point BP or STOP detected, the process table is updated (UPD P.TAB, block 58) by recording the state taken by the process under test and the row where the process has been stopped.

In addition, if the process originating the message is the current one (block 59) suitable commands are sent to the terminal screen to display the event (block 60).

The main monitor then returns to block 50.

In case the message sent by the process under test is due to the condition VISUAL asserted, the main monitor steps to block 60.

The case is now considered in which the message received by the main monitor has been sent by the control keyboard.

In this case the main monitor steps from block 51 to block 61.

The main monitor checks for the correctness of the received commands which may request the execution of some basic operation.

- to see the status of the processes under test
- to select a generic process under test as current process
- to see the list of break points which have been set for a generic process
- to insert or remove break points in or from the break point list of a current process
- to read or write process variables
- to start a stopped process.

Once the correctness has been verified the main monitor performs the required operations (block 62) and provide a corresponding displaying on the screen. Then returns to block 50.

The main monitor may further receive messages from background monitor. By these messages the background monitor, which will be described in the following, signals possible changes in the status of processes which have been controlled in background.

The only function which the main monitor has to perform, on receipt of such messages is therefore to update the status of the process table P.TAB (block 63). This is mandatory because the main monitor records (for referring to the user on command by keyboard) the status of all processes under test. Once the process table is updated the main monitor returns to block 50.

Figure 9 shows in flow diagram the operations performed by the background monitor.

Whilst the main monitor, as already seen, has the task to signal to operator the status of the current process, but cannot, restart stopped processes on its own initiative, perform read or write operation on a variable and more generally test operations on programs to be tested, the background monitor is provided purportely for performing these task, without need of the operator intervention.

The user may preset, before starting the monitoring processes, or dynamically in the course of the processes, some test routine or TEST SCRIPT.

These routines are selectively activated, generating a testing process each time the function x:F detects a background break point in the course of a process under test.

The background monitor is invoked and automatically activated by the activation of the VDB monitor (blocks 70,71) and the background monitor checks if there are messages in the queue Q2.

If a message is present (block 72) the background monitor tests if the message is due to the detection of a background break point or not (block 73).

In the affirmative case the background monitor updates the status of its process table (the background monitor manages its own process table where the only processes are recorded for which a background breakpoint has been detected), then it sends a message to the main monitor (the main monitor too has to update the status of its process table), identifies a test routine (FIND TEST SCR.) related to the break point and referenced by a code (FLAG) in the break point table and generates a "child" test process with the FORK primitive. The child process may insert, remove brake points, read or write variables and restart the process under test.

Once these operation are performed (block 74) the background monitor steps to block 72 to test the presence of the other messages in Q2. If the received message is not due to a breakpoint, it is due to a child testing process which requests the execution of some of the already indicated operations.

Therefore the background monitor steps from block 72 to block 75 and recognizes the operation to be performed.

If the insertion or removal of a breakpoint is requested the background monitor steps from block 75 to block 76.

The correctness of the request is verified and a semaphore is set (SET SEM BPT) to prevent break point table access interference by the main monitor.

The break point table (BPTABLE is then updated with the insertion/removal of the break point and the semaphore is reset.

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Eventually an operation completed message is sent in queue Q3 to the testing process TEST SCRIPT (block 77).

From block 77 the background monitor returns to block 72.

If the message received by the background monitor (from a testing process) requests the restart of the PUT for which the testing process has been performed, the background monitor steps from block 72 to block 73, then to block 75 and to block 78.

In block 78 the background monitor updates its process table, sends a message to the main monitor to have the main monitor process table updated and sends a message to queue Q3 in order that the process under test (thanks to the function x-F) can restart.

From block 78 the background monitor then returns to block 72.

If the message received by the background monitor requests the reading or writing of a variable, the background monitors steps from blocks 72,73,75 to block 79.

The existence and consistency of the needed resources is first tested. Then the operation is performed and a message is sent to the testing process (msg>Q3>TEST.SCR) through queue Q3.

Even in this case the background monitor returns from block 79 to block 72.

The preceding description is related to a preferred embodiment of the tools used for performing the method of the invention.

It is however clear that several changes can be made without departing from the scope of the invention.

For example in case the processes under test are not interactive with the user, a second terminal for their starting is not required.

Likewise the partitioning of the monitor program in modules and its activation as a plurality of distinct processes is only a preferred way of implementation and the monitor program may costitute a single executable file.

Even the preprocessing of a source program to be tested and its compilation may be performed "off line" provided the preprocessed and compiled program is loaded in the system used for performing the method.

The use of the C-language is given by way of example and the method may be used with any language and any operating system capable of managing multiprocessing systems.

Claims

1. Method for programs debugging and testing of their correctness, the method being performable in a data processing system provided with at least a first user terminal having display and keyboard, the method being characterized by the following operations:
   - loading a first monitoring program and at least a second source program to be tested, comprising a plurality of executable instruction rows, in said system,
   - loading in said system at least a second object program, obtained from said second source program, by a preprocessing which includes, at each executable row a call to a control routine,
   - activation, through said first user terminal of a first monitoring process based on said first monitoring program and activation of a second process executing said second object program, said activations occurring in any order,
   - signalling by said second process to said first process, by means of a first message stored in a first message queue, of the occurred activation of said second process,
   - detection of said first message by said first process and signalling to said second process with a second message, stored in a second message queue, of modalities to be followed in the further proceeding of said second process.

2. Method as in claim 1 where said data processing system is provided with a second user terminal having display and keyboard, the activation of said second process being performed through said second terminal.

3. Method as in claim 1 comprising the further operations of:
   - loading in said system at least a third source program to be monitored,
   - loading in said system at least a third object program obtained from said third source program by a preprocessing which includes at each executable row of said source program, a call to a control routine,
   - activation of a third process executing said third object program.
   - signalling by said third process to said first process, by means of a third message stored in said

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first message queue, of the occurred activation of said third process,
- detection of said third message by said first process and signalling to said third process, with a fourth message stored in said second message queue, of modalites to be followed in the further proceeding of said third process.

4. Method as in claim 1 where said first monitoring program comprises a main module and a background module, the activation of said first monitoring process involving the activation of two distinct processes respectively a main monitor and a background monitor, said main monitor and background monitor communicating each with the other and with said second process by means of said first, a third, and said second message queue said queues being respectively related to said main monitor, said second process and said background monitor.

5. Method as in claim 4, comprising the further operation of:
- loading in said system at least a test routine (TEST SCRIPT) to be activated at a predetermined point of said second process,
- identification of said predetermined point by means of a background break point referring to said test routine in a break point table accessible for read/write operations by said main monitor and background monitor and accessible for read operation by said second process,
- detection by said second process of said background break point and corresponding forwarding of a message to said background monitor,
- generation and activation by said background monitor of a child testing process, based on said test routine referred to by said background break point.

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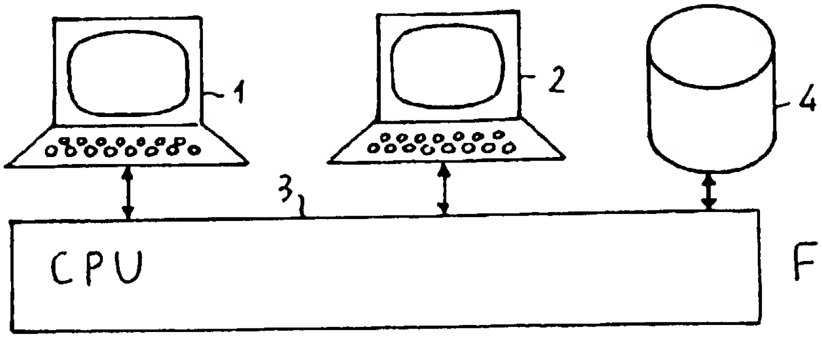

FIG. 1

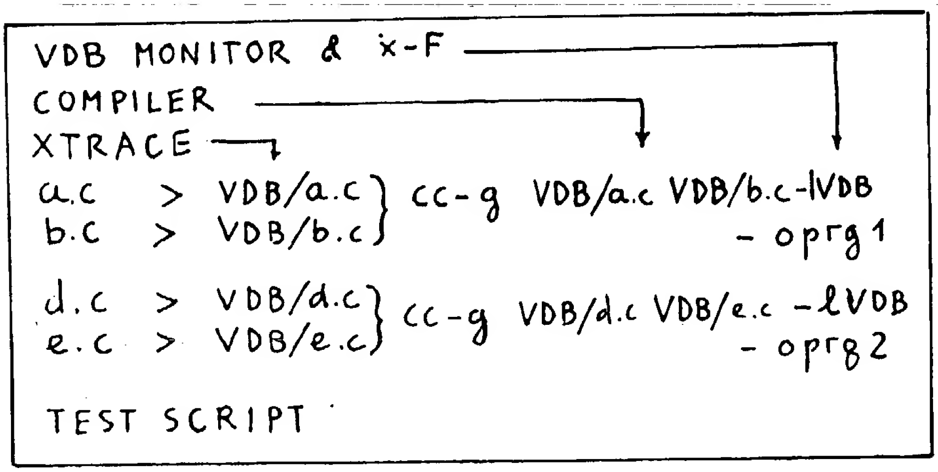

FIG. 2

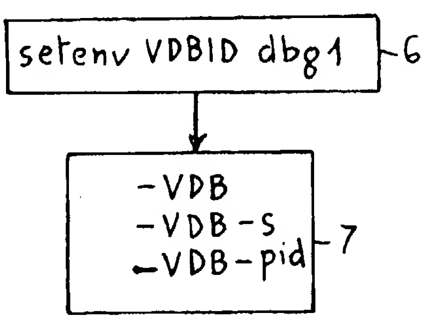

FIG. 3

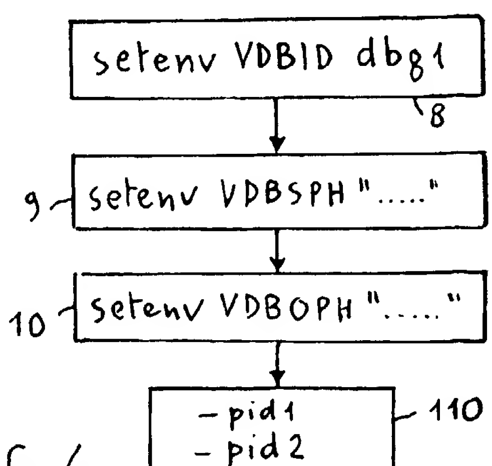

FIG. 4

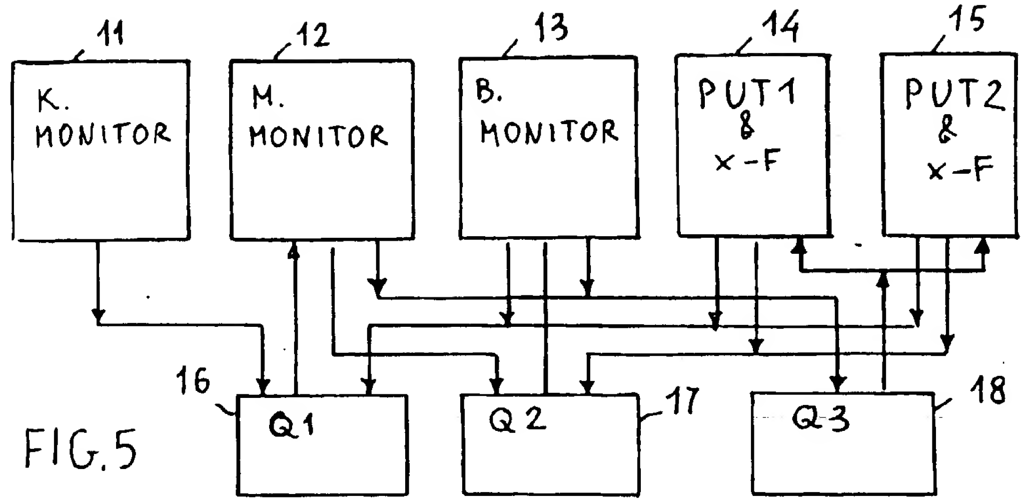

FIG.5

FIG.6

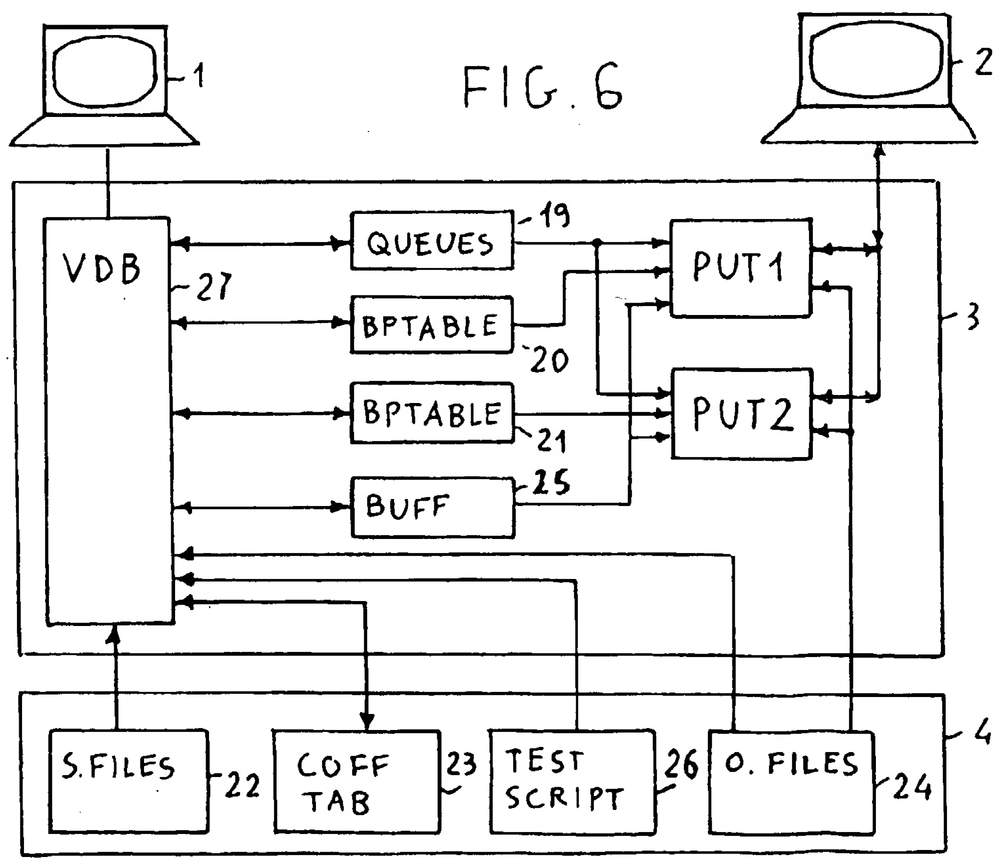

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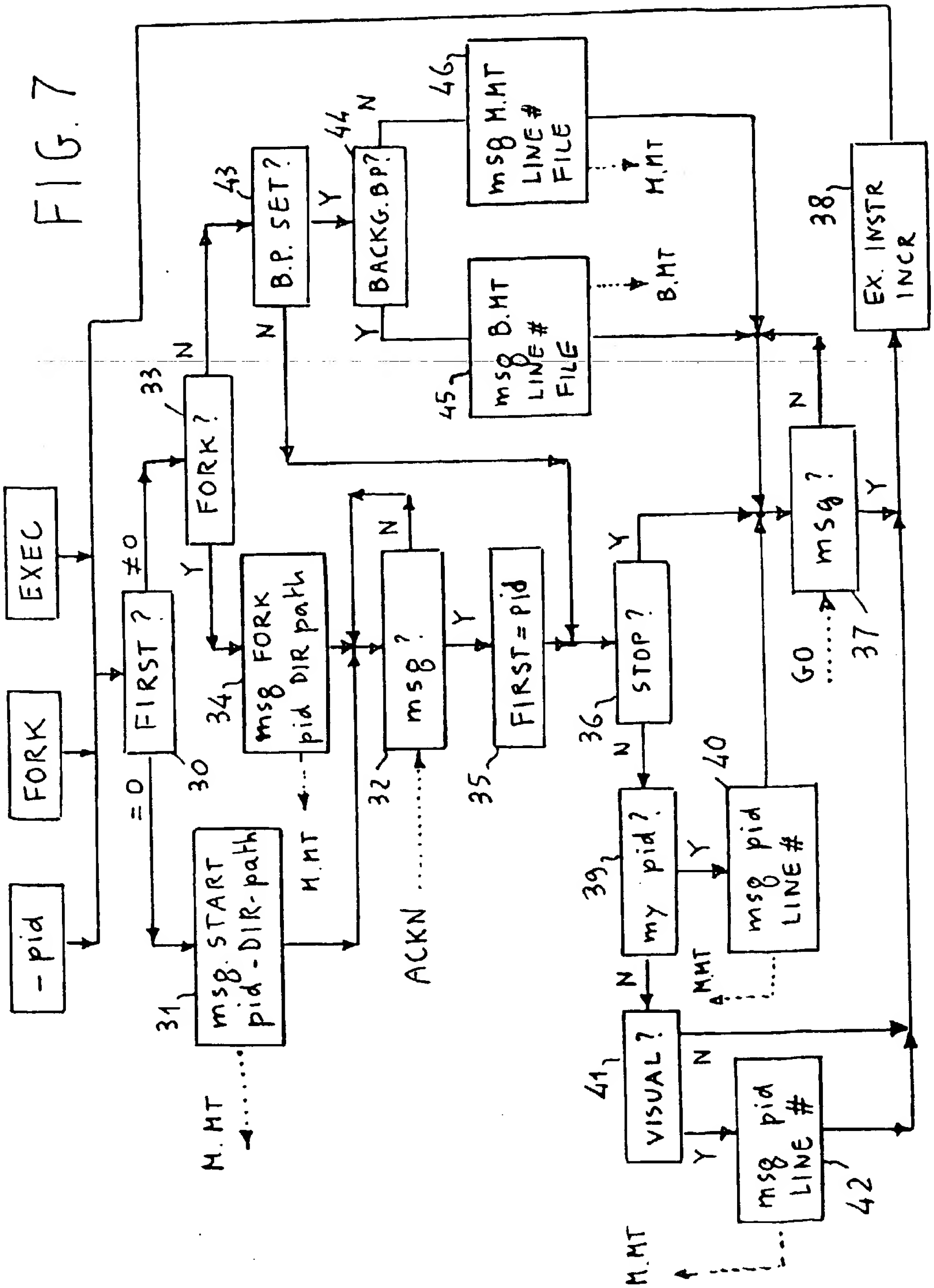
FIG. 7



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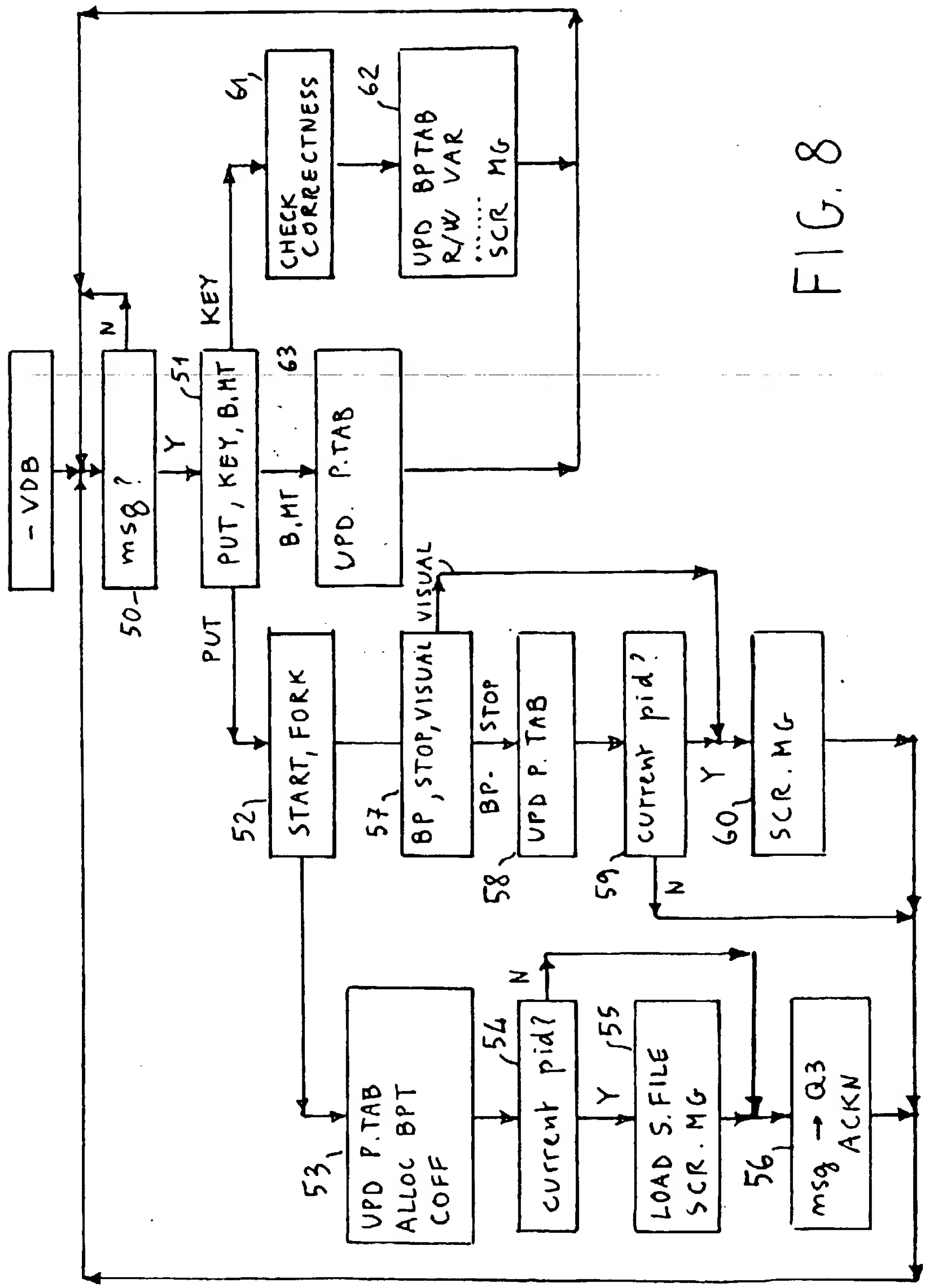
- VDB
50
msg ?
N
Y
51
PUT , KEY , B.MT
KEY
61
CHECK CORRECTNESS
62
UPD BPTAB
R/W VAR
....
SCR MG
B.MT
63
UPD. P.TAB
PUT
52
START, FORK
57
BP , STOP, VISUAL
VISUAL
BP-
STOP
58
UPD P. TAB
59
current pid ?
Y
N
60
SCR . MG
53
UPD P.TAB
ALLOC BPT
COFF
54
current pid?
N
Y
55
LOAD S. FILE
SCR . MG
56
msg → Q3
ACKN

FIG. 8

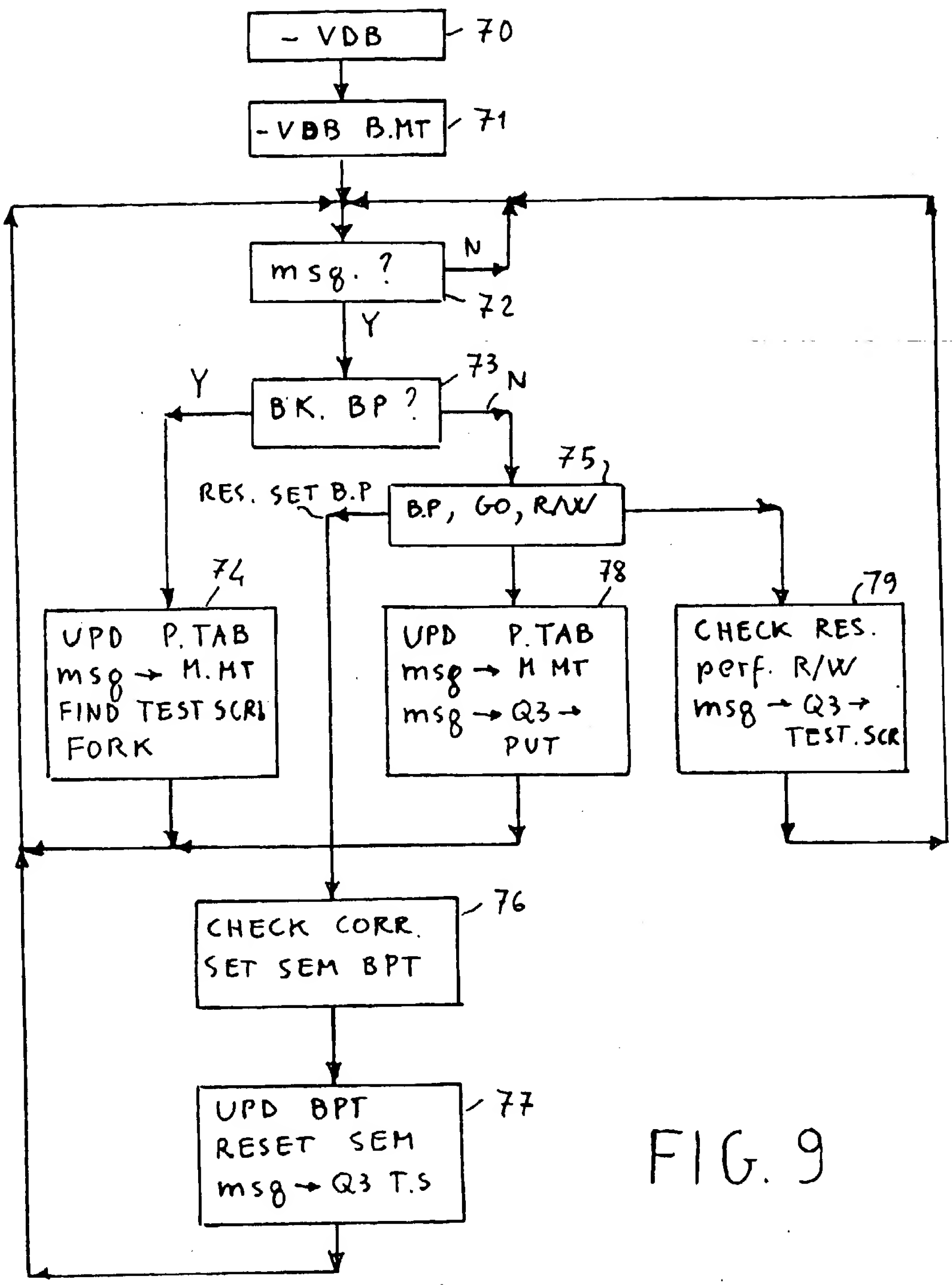

FIG. 9

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